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G1A
G1N

(54) Position measurement

(57) A precise angular position detector comprises an N, N+M (M may be 1) inductosyn, i.e. a pair of relatively rotatable discs, one bearing two windings 13, 18 having N and (M+M) pitches per revolution thereby to produce a vernier effect, and the other bearing a pair of quadrature pick-offs for each winding. The output of each pick off pair is converted to a digital angle signal, the signal from one pair being used as a fine measure and a combination of both signals providing a coarse measure, both measures being combined to give the total angle. If both angle signals are not zero when the discs are in a relative reference position, e.g. due to inaccurate printing of the windings, a fixed error in the total angle is produced. Such angle is measured by calibration and a compensatory quantity is added to one of the fine and coarse measures prior to their combination. Linear position detection is possible in like manner.

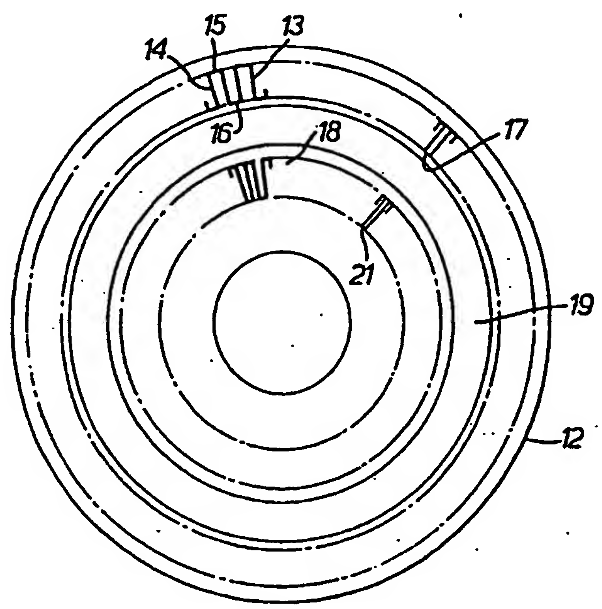

FIG. 1.

The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.
The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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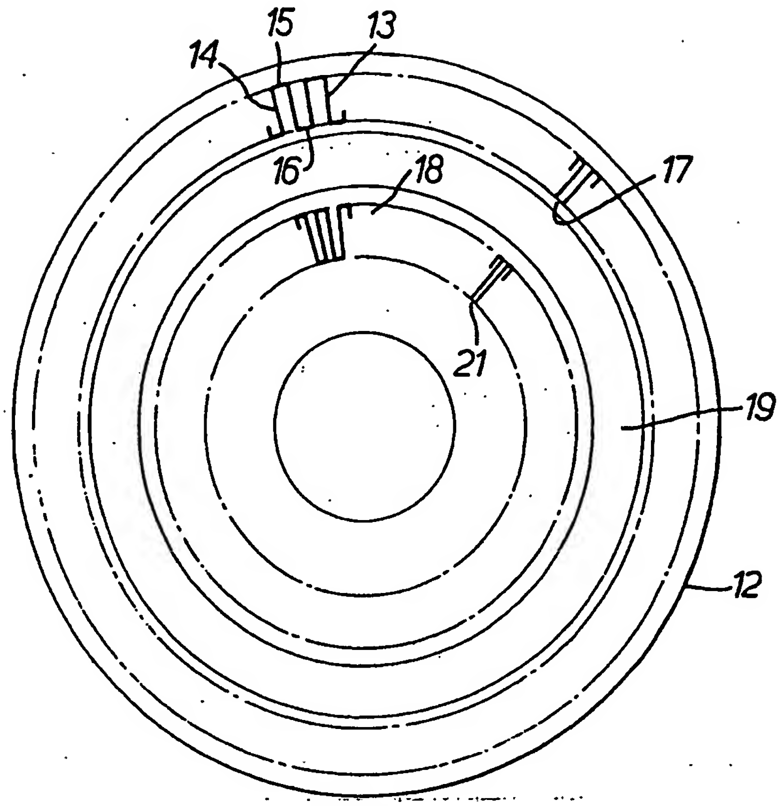

FIG.1.

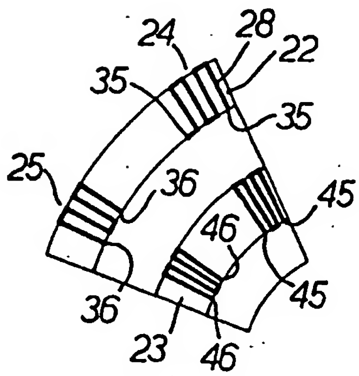

FIG.2.

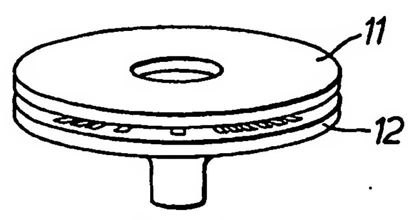

FIG.3.

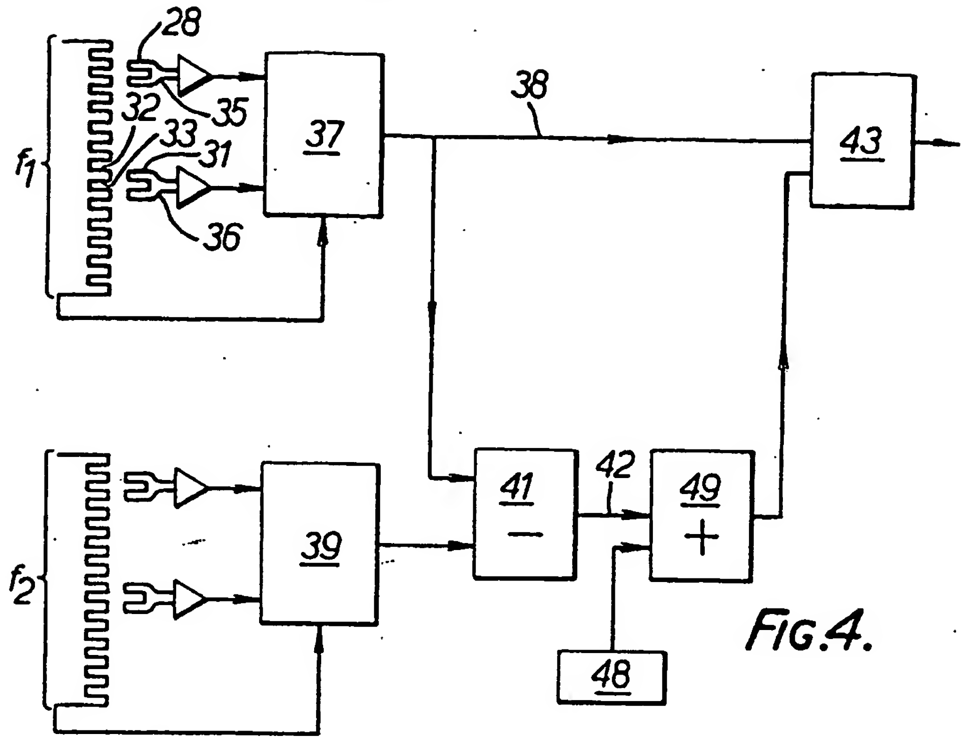

FIG.4.

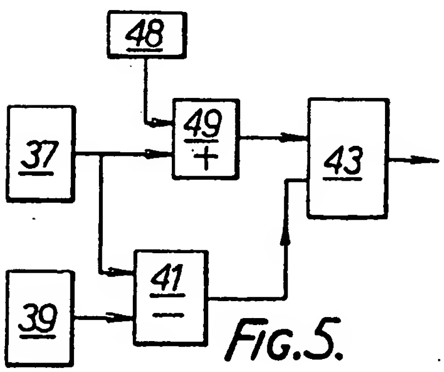

FIG.5.

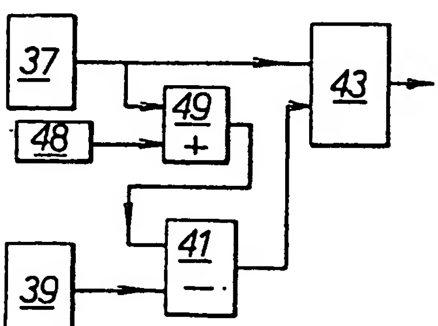

FIG.6.

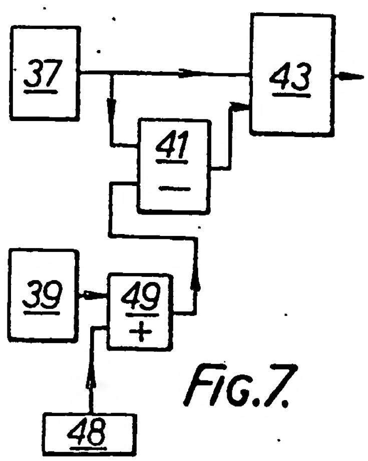

FIG.7.

SPECIFICATION

Position detector

This invention relates to a detector of the position of one member in relation to another, and although it is of particular application to detecting relative angular position, for example between two shafts, or between a shaft and a housing, it is also applicable to detecting the position of a member which is movable linearly relatively to another member.

An object of the invention is to provide means for providing a particularly accurate position signal by using coarse and fine components, but without having to have separate drive means for deriving either of those components, and for providing convenient means for correcting any zero error between the coarse and fine component signals.

According to one aspect of the present invention, a position detector comprises two windings, a pick-off for each winding, means for deriving from the outputs of the pick-offs coarse and fine position signals, and means for supplying a compensating signal for zero correction between the pick-off outputs.

One known method for providing a position signal uses an inductosyn which consists of an elongate or arcuate winding, together with a pick-off movable along the length of the winding and consisting of two separate short sections of the winding which are spaced in quadrature to each other in relation to the pitch of the winding. The outputs of the two sections can be combined to provide a measure of the relative position, but the output signal varies cyclically as movement along the elongate winding continues, so that although a precise position within a cycle can be indicated, there is ambiguity as to which cycle represents the absolute relative position, and it is necessary to provide additional means for resolving that ambiguity.

One method of resolving the ambiguity is to provide a second inductosyn in which the number of turns per unit length of the winding is one different from the number of turns per unit length in the other winding, and that can operate in a manner analogous to that of a vernier. That system may be described as an N, N± 1 inductosyn.

According to another aspect of the invention, an N, N± 1 inductosyn includes means for adding in a compensating signal representing an angular zero displacement between the two inductosyn windings.

Although it is theoretically possible to get an accurate measure of relative position using an N, N ± 1 inductosyn, it is known that zero errors can arise due to the fact that the two inductosyns outputs are not both precisely zero at a reference position. Correction can in theory be achieved by a small movement of one inductosyn in relation to the other to set the zero, but that is impracticable in many applications.

Where it is relative angular position that is to be detected it is convenient if the inductosyn comprises two coaxial discs with their faces closely spaced from each other. It is possible for the N, N±1 windings to be formed or printed on one of the faces, and for the two pick-off windings to be formed on the face of the other disc, so that there are only the two relatively movable components which can be easily attached for example respectively to a shaft on the housing.

Instead of providing mechanical adjustment between the components, it has been discovered that it is possible to correct for any angular zero error by adding in a digital signal representing the zero error angle in the circuit which is used for deriving from the pick-off outputs a combined coarse and fine signal representing absolute angle The amount of compensating angle to be added can be calculated after one or two tests after manufacture of the inductosyn.

In a particular application, the output from one inductosyn pick-off is used to provide a fine position signal, and is also combined with a signal derived from the other inductosyn winding to provide a coarse position signal. The compensating signal can be added to the coarse position signal, and then they can be combined with the fine position signal to produce an accurate absolute signal.

According to a further aspect of the present invention, an angular position detector comprises a pair of electrical windings whose pitches are in the ratio N:N±1 each winding being associated with a relatively movable pick-off, means for deriving from one pick-off a first signal representing with accuracy the relative angle of the pick-off to the winding within one winding pitch, means for deriving from the two pick-offs a signal representing with lower accuracy the absolute relative angle of the pick-offs to the windings, and means for adding a correction signal representing an error angle, and combining means for producing a corrected signal representing the absolute angle with the accuracy of the first signal.

The invention may be carried into practice in various ways, and one embodiment, together with some modifications will now be described by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a plan view of one plate of an inductosyn;

Figure 2 is a plan view of a pick-off for use on the second plate of the inductosyn of Figure 1;

Figure 3 is a sketch showing the arrangement of the two inductosyn discs;

Figure 4 is a block diagram showing the electrical connections from the inductosyn of Figures 1-3 and;

Figures 5, 6 and *7* are block diagrams of alternative circuit arrangements.

The inductosyn comprises two closely spaced relatively rotatable facing plates 11 and 12 each of which is connected to two different shafts or the equivalent, the relative angular position of which is to be indicated.

One of the plates 12 carries two windings and each winding is in the form of a deposited copper strip 13 of generally castellated form with a number of radially extending bars 14 interconnected alternately at the inner and outer ends by circumferentially extending bars 15 and 16. The winding extends continuously at constant radius around the plate 12,

except at one point indicated at 17 where there is a discontinuity and where the winding can be energised by an alternating voltage at a frequency f_1. The radial bars are of equal pitch and in the example being described there are 256 of them in the complete circumferential winding. They are deposited on an insulating surface, and define effectively 128 turn or cyles each including two bars 13.

The other winding 18 is of similar form to the winding 13, but is spaced radially within it, and is separated from it by a conducting continuous ring 19 which provides elastrostatic shielding between the two windings. The second winding is energised at 21, with alternating voltage at a frequency f_2. The bars in the second winding are also equally spaced, but in the example being described there are only 254 bars in the complete circumferential winding, that is one less cycle than in the outer winding 13. It would be possible to have 258 bars so that in either case the difference between the number of cycles or turns in the two windings is one, but it will be convenient merely to describe operation as if there were 256, and 254 bars in the respective windings.

Each of the windings is associated with a pick-off carried on the second plate 11. There are two pick-offs 22 and 23, one for each of the windings 13 and 18. Each pick-off consists of blanks of two short sections 24 and 25, of winding similar to the winding it is to co-operate with, but the two sections 24 and 25 are phase displaced by 90° so that if a bar such as 28 in Figures 2 and 4 on one pick-off section is in line with a bar such as 29 in Figure 4, on the winding for that pick-off, then for the other pick-off section a bar such as 31 is mid-way between the bars 32 and 33 on the winding 13. The pick-off is shown in simple form in Figures 2 and 4, but in fact there are many more groups of bars connected together in series so that almost the complete ring on the plate 11 carries bars forming part of the pick-off with half of the bars being at one phase in relation to the winding, and the other half in quadrature with them. It can be shown that for any angular position of the plate 11 in relation to the plate 12, the pick-off outputs indicated at 35 and 36, and 45 and 46 are respectively proportional to sin and cos $(N-1)\theta$ where θ is the angular position from a reference position, and N is the number of poles having on the outer winding and is equal to 128. By combining the outputs 35 and 36 from the two pick-off sections of the outer pick-off in a combiner 37, it is possible to produce at 38 a signal representing in digital form the angle $N\theta$ However, sin $N\theta$ varies cyclically N turns in a complete revolution of the plate 11 in relation to the plate 12, and although the incremental angle rom the start of a cycle can be indicated very accurately, the absolute angle cannot be determined directly.

However, a similar measurement of $(N-1)$ o is taken from the pitch off 23 co-operating with the second winding 18 with 254 bars, and it can be shown that if the two digital numbers derived in the converters 37 and 39 are substracted one from the other in a subtractor 41, the output 42 from the substractor represents the absolute angle, although not with great precision.

Thus, $\theta N-\theta(N-1)=\theta$

A combiner 43 is arranged to combine the signals at 38 and 42, namely the accurate $N\theta$ and the coarse θ to produce a measure of the absolute angle θ with the accuracy of the $N\theta$ signal at 38.

Inaccuracy may arise due to coupling between the sin and cos signals, or due to the converters 37 and 39, and that results in random error, the existance of which has to be recognised.

However, a predictable error can arise if the two signals at 38 and 42 are not at 0 together in a reference relative position of the plates 11 and 12.

That may arise due to an inaccurate printing of the windings on the plates or other fixed inaccuracies and compensation can be achieved by injecting a constant digital signal corresponding to the sum of all the angular misalignment at 48 to be added to the absolute angle signal in an adder 49 before combination at 43 with the precision signal 38.

The amount of compensation required can be determined by examining the uncompensated output at 43 in relation to a known angle of rotation of the marker 12.

The compensation angle number could be added at various places in the output circuit as indicated in Figures 5, 6, and 7, where similar components have the same numerals as in Figure 4.

It will be appreciated that an accurate measure of relative angular position can be obtained with only the two relatively moving components 11 and 12.

N, N±1 inductosyn windings have been referred to, but the invention of using fixed angle correction is also applicable to N, N±M windings which are useful if the angle to be measured varies only within a limited angle of 360°/M.

CLAIMS

1. A position detector comprising two windings, a pick-off for each winding, means for deriving from the outputs of the pick-offs coarse and fine position signals, and means for supplying a compensating signal for zero correction between the pick-off outputs.

2. A detector as claimed in Claim 1 in which each winding is an elongate winding, and each pick-off is movable along the length of the winding and consists of two separate short sections of the winding which are spaced in the winding which are spaced in phase (preferably in quadrature) to each other in relation to the pitch of the winding.

3. A detector as claimed in Claim 2 in which for each pick-off the outputs of the two short sections are combined to provide a measure of the relative position of the pick-off in relation to its winding.

4. A detector as claimed in any of the preceding claims in which the number of turns per unit length is different from the number of turns per unit length of the other winding.

5. A detector as claimed in Claim 4 including means for adding in a compensating signal representing an angular zero displacement between the two windings.

6. A detector as claimed in any of the preceding claims in which the two windings are carried or formed on a surface of one component and the two

pick-offs are carried or formed on a confronting surface of another component.

7. A detector as claimed in Claim 6 in which the two components are concentric relatively rotatable discs.

8. A detector as claimed in any of the preceding claims in which the compensating signal is a digital signal calculated from experimental tests.

9. A detector as claimed in any of the preceding claims in which the output from one pick-off provides a fine position signal, and the combined outputs from the two pick-offs provide a coarse position signal.

10. A detector as claimed in Claim 9 in which the fine and coarse signals are added together with the compensating signal to produce an accurate absolute signal.

11. An angular position detector comprising a pair of electrical windings whose pitches are in the ratio N:N±1, each winding being associated with a relatively movable pick-off, means for deriving from one pick-off a first signal representing with accuracy the relative angle of the pick-off to the winding within one winding pitch, means for deriving from the two pick-offs a signal representing with lower accuracy the absolute relative angle of the pick-offs to the windings, and means for adding a correction signal representing an error angle, and combining means for producing a corrected signal representing the absolute angle with the accuracy of the first signal.

12. A position detector constructed and arranged substantially as herein specifically described with reference to Figures 1-3 or Figure 4 or either of those Figures as modified with reference to Figures 5, or 6 or 7 of the accompanying drawings.

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